Research and Development Issues for the Future

Martin Rymes

Satellite-based solar energy resource estima-
tion methods have been developed to such an
extent that the R&D issues have shifted from
primary model development to refinement of
models. These issues tend to separate into
three primary areas: physics, surface/satellite
correlations, and innovation applications. The
critical physics issue is the determination of
accurate cell-by-cell/frame-by-frame estimates
of atmospheric contaminants such as aerosols,
precipitable water, and ozone, as well as
refined algorithms for estimating the opacity
and thickness of clouds. In the future, surface-
based measurements of these atmospheric
properties will be supplanted by satellite-
based estimates, preferably through multiband
spectral analysis from the same satellites that
provide the visible cloud-cover image. The
refinement limit is the smallest [(grid-cell) x

(time-interval)] nugget for which the uncer-
tainty of satellite-based estimation exceeds the
uncertainty of a comprehensive ground-based
measurement network. When satellite-based
techniques are pushed beyond this limit, a
new metric for accuracy will be developed that
will loosen (and ultimately sever) the reliance
on high time-series correlations with surface
measurement stations. Such a metric may take
the form of cumulative frequency distributions
of estimated energy levels and/or days of
autonomy. Finally, new applications for satel-
lites will be developed that meet future energy
developers' needs in ways that surface meas-
urement networks never can. Examples of
these applications are forecasts of "blackout
storms," detailed qualitative microscale maps,
and regional maps of "solar climate" zones.

Research and Development Issues
for the Future

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Near Future: next 5 years
Far Future: 6 - 20 years

Issues We Share

* Input: data sources
* Process: model refinements
* Validation: correlation with
     surface measurements
* Output: uniquely satellite-based
     products

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Input: Data Sources

Aerosols

Anisotropic Diffuse Sky

Backscattering Ratio

Clouds:
- Height
- Opaque and Translucent Amount
- Thickness

Ozone

Precipitable Water

Snow & Ice

Turbidity

Sources of Input Data: Today & Near Future

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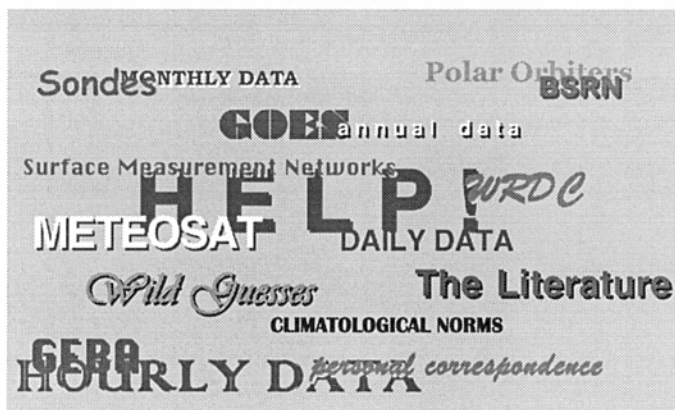
Sources of Input Data: Far Future

Same satellite makes ALL necessary measurements through multispectral scans

- Ensures space/time coincidence
- BUT must find spectral correlations to:
  - aerosols
  - cloud thickness
  - precipitable water

EARTH
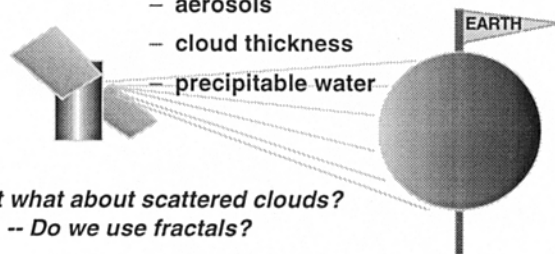
But what about scattered clouds?
-- Do we use fractals?
Or the 3 GB/day of data?

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Model Refinements: Near Future

- Try to match surface measurements
- Need GOOD surface measurements
- 9 or more surface stations per grid cell
- Soundings located near surface network
- Soundings, surface, satellite at the same time period, not differing years!

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Research and Development Issues for the Future

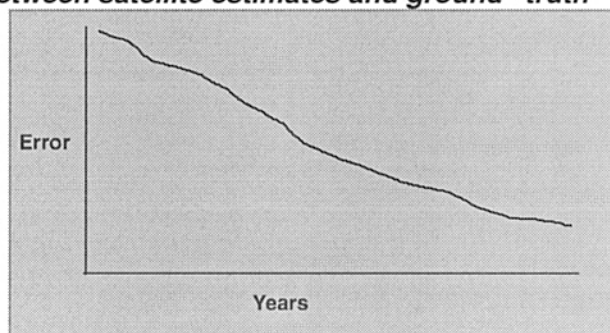## Model Refinements: Far Future

ASSUME:
- We trust the physics
- We trust the inputs
- We trust the satellite multispectral correlations to inputs

EMPHASIS:
- Proper satellite bandwidths for maximum information extraction
- Image-by-image autocorrelation and trend analysis
- Sophisticated image enhancement techniques

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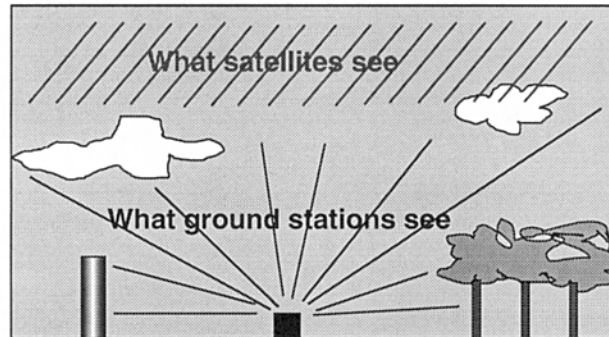## Correlation with Surface Measurements: Near Future

Researchers will still try to reduce the "error" between satellite estimates and ground "truth"

Error

Years

However, "error" cannot be reduced below 5 intrinsic "nuggets"...

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Correlation with Surface Data:
Far Future

Nugget #3: Relative-Size Problem
    One satellite pixel = vast land area
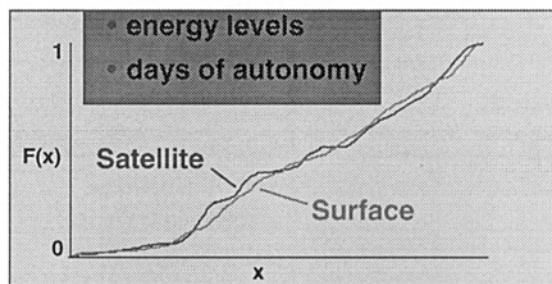
Nugget #4: Wind Problem
    Satellite "snapshots" do not observe
    changing cloud patterns WITHIN
    time interval

Nugget #5: Ground "Truth" Problem
    The best surface measurements have
    intrinsic uncertainty...but most are not
    the best!

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Correlation with Surface Data:
Far Future

• **Replace time-series matching with correlations
that are useful to solar energy community:**

    − **cumulative frequency distributions of:**

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Uniquely Satellite-Based Products:
Near Future

Detailed maps -- of *WHAT*?
(Remember those nuggets)

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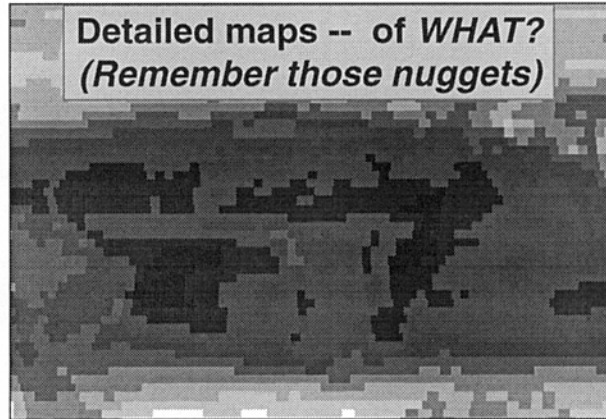
Uniquely Satellite-Based Products:
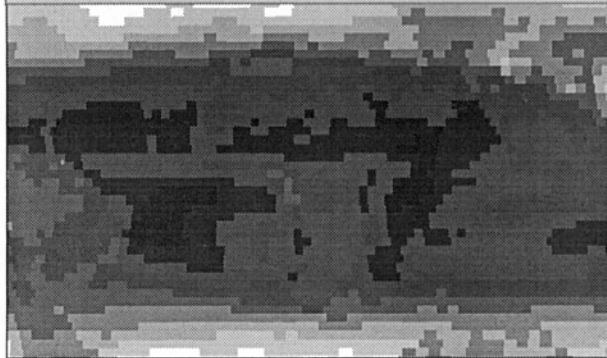## Near Future
Solar Weather Forecasting

- Prediction of blackout days
- "Choppy" clouds -- bad for solar thermal systems
- Rough estimates of available solar energy

Benefits:

- Plant shutdowns are anticipated
- Hybrid switchovers are planned
- Home use: "careful" days are scheduled

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Uniquely Satellite-Based Products:
Far Future

> *Detailed "space truth" solar energy maps*

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Uniquely Satellite-Based Products:
Far Future
"Weather Channel" Solar Forecasts

- **Widely available on common television stations**

- **As accurate as standard meteorological forecasts**

- **Up to 5 days projected**

- **Creates consumer "solar awareness"**

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Uniquely Satellite-Based Products:
Far Future

Detailed "Solar Climate" Maps

* 20 - 200 standard zones based on:
  - seasonal monsoons
  - monthly diurnal cycles
  - clear / scattered clouds / cloudy
  - topography, elevation, & latitude
  - precipitable water

* 1 km resolution

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Uniquely Satellite-Based Products:
Far Future

Detailed "Solar Climate" Maps

* Static zones aid in domestic, industrial, and utility planning, similar to:
  - soil maps
  - topographic maps
  - water maps

* Measurement and research stations will be deployed in unknown zones

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Far Future:
The Death of the Surface
Measurement Network?

NO.

* People live on the Earth. "Space truth"
  will never replace "ground truth."
* Satellite weather forecasts are always
  supplemented with the local weather
  station. Solar is no different.
* New satellite-based methods require
  new surface-based measurements
  and networks.

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CONCLUSIONS

Near Future: • Surface provides most input data

• Surface determines truth

• Satellite-derived products are spatially detailed
clones of surface products

Far Future: • Satellite provides most input data

• Satellite determines truth

• Satellite-derived products radically
different from surface products

• Surface stations provide validation and
"reality" link

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